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OPTIMIZATION CUTTING PARAMETERS WHEN GRINDING ШХ15 STEELS USING HAI DUONG GRINDING WHEEL

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ABSTRACT

This paper presents an experimental research to build two regressions of the relationship between machining surface roughness and cutting parameters when grinding the ШХ15 steels by Hai Duong grinding wheels. Two types of Hai Duong grinding wheel were used that are Cn46.TB1.G.V1.400x40x203x50m/s and Cn46.CV1.G.V1.400x40x203x35m/s. Three cutting parameters were considered that are depth of cut, feed rate, and workpiece velocity. Genetic algorithm was used to find the values of cutting parameters for minimum value of surface roughness. By the proposed method of this work, the optimization values of cutting parameters was determined for each pair of workpiece - wheel.This method can be used to improve the quality of machining surface in grinding prosesses.

KEYWORDS: Cylindrical Grinding, Surface Roughness, Cutting Parameters, ШХ15 Steel, Optimization & Hai Duong Grinding Wheel

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Original Article

INTRODUCTION

Grinding is a manufacturing process with unsteady process behavior. This process has the complex characteristics that determine the technological output and quality. The assessment of the grinding process quality usually includes the microgeometric quantities of the many components. Study on grinding field focus in the large of the range.In which, study on optimising the cutting parameters had done by many authors: Optimization value of depth of cut, velocity of workpiece, grinding wheel speed and numberof passes when grinding AISI 5120 by Al_2O_3grinding wheel[1]; Optimization value of depth of cut, velocity of workpiece, grinding wheel speed when grinding EN24 steel byAl_2O_3grinding wheel [2, 3]; Optimization value of grinding wheel speed, depth of cut and feed rate when grinding EN-8 by A10K5V wheel [4]; Optimization value of grinding wheel speed, feed rate, depth of cut, grain size and concentration of cutting fuild when grinding AISI 4140 [5].ШХ15 steel is representing for bearing steels. Vietnam have imported those steels from Rusia with large quantity, for technology grinding by Hai Duong grinding wheel, the wheel has manufactured by Hai Duong grinding wheel factory (Vietnam). In this paper, study on optimization cutting parameters when grinding ШХ15 steels using Hai Duong grinding wheel.

GRINDING EXPERIMENT

Workpiece

Workpiece in this work is ШХ15 steel which had heat treated for archived 58÷60HRC in hardness. Shape and dimesion of workpiece of materials is show in Figure 1. The equivalent sign of IIIX15 steels of countries are

described in Table 1.

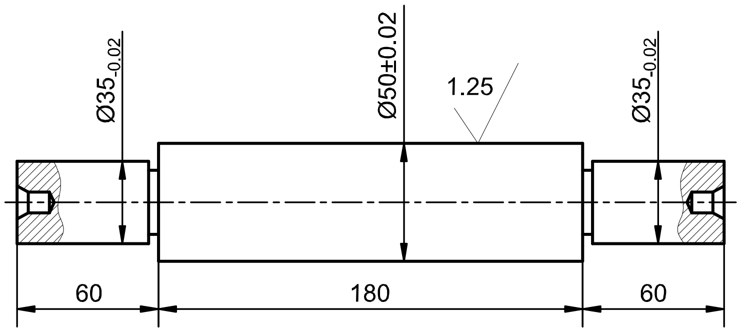

Figure 1: The Geometry of workpiece

Table 1: Equivalent Sign of Steels of Countries

Vietnam	Russia	American	Japan
OL 100Cr1.5	ШХ15	52100	SUJ2

Machine Tool and Grinding Wheel

Grinding experiments were conducted on an 3b153 cylindrical grinding machine (Russia).Two type of Hai Duong grinding wheel factory's had used in this work which are Cn46.TB$_1$.G.V$_1$.400x40x203x50m/s and Cn46.CV$_1$.G.V$_1$.400x40x203x35m/s.

Surface Roughness Tester

The measurements were carried out with a Mitutoyo Surftest SJ-201 stylus type surface texture-measuring instrument. Each ground component was measured three times. The surface roughness response for each test is the average reading of three consecutive measurements.

Experimental Design

Matrix of D-optimal designs with three input parameters which is used in this work, each parameter have three levels of value, quoted in Table 2 and Table 3.

Table 2: Levels of Input Parameters When Grinding ШХ15 Steel

Levels	Code Value	Input Parameters		
		t(mm)	S_d (m/min)	v_{ct} (m/min)
High level	+1	0.01	0.75	37.68
Medium level	0	0.075	0.60	31.40
Low level	-1	0.05	0.45	25.12

Table 3: Matrix of D-Optimal Designs

Run	t	S_d	v_{ct}
1	0	-1	-1
2	0	1	-1
3	0	-1	1
4	0	1	1
5	-1	0	-1
6	1	0	-1
7	-1	0	1
8	1	0	1
9	-1	-1	0

Table 3: Contd,.

10	1	-1	0
11	-1	1	0
12	1	1	0
13	0	0	0

Experimental Conditions

It is important to conduct the experiments under chatterfree conditions and to keep the cutting speed (34 m/s), the depth of dressing (0.01 mm), the feed rate of dressing (1 m/min) and the coolant flow constant (25 litres/min). Experimental investigations require precise process set-up to ensure that the trials are done according to plan. Errors and inaccuracies at this stage could nullify experimental validity.

EXPERIMENTAL RESULTS AND OPTIMIZATION

Analysis of Variance (ANOVA) for Surface Roughness

The experimental results were investigated and listed in Table 4. In this study, ANOVA was used to analyze the influence of grinding conditions on the surface roughness. This analysis was performed with 95% confidence level and 5% significance level. This indicates that the obtained models are considered to be statistically significant.

Table 4: Experimental Matrix when Grinding ШХ15 Steel

Run	t	S_d	v_{ct}	Ra	
				$Cn46.TB_1.G.V_1$ 400x40x203x50m/s	$Cn46.CV_1.G.V_1$ 400x40x203x35m/s
1	0	-1	-1	0.37	0.41
2	0	1	-1	0.48	0.50
3	0	-1	1	0.44	0.48
4	0	1	1	0.57	0.58
5	-1	0	-1	0.39	0.40
6	1	0	-1	0.46	0.52
7	-1	0	1	0.42	0.46
8	1	0	1	0.55	0.56
9	-1	-1	0	0.35	0.38
10	1	-1	0	0.44	0.48
11	-1	1	0	0.42	0.50
12	1	1	0	0.59	0.60
13	0	0	0	0.46	0.52

The ANOVA results for amplitude of feed force was illustrated in Table 5 that the contributions of each factor on surface roughness were listed in the last column. It seems that the most important factors affecting on the surface roughness were depth of cut and feed rate (from 39.819 %to 42.854%). And, the third factor influencing on the surface roughness was workpiece velocity (14.465% with $Cn46.TB_1.G.V_1$400x40x203x50m/s grinding wheel and 15.32% with $Cn46.CV_1.G.V_1$400x40x203x35m/s grinding wheel).

Table 5: Results of ANOVA for Surface Roughness

Source	Sum of Squares	Degree of Freedom	Mean Square	F-Value	Prob > F	Percent Contribution (%)
Cn46.TB1.G.V1400x40x203x50m/s						
Number of obs:	13		R-squared:		0.9504	
Root MSE:	0.0234		Adj R-squared:		0.9007	
Model	**0.0631**	**6**	**0.0105**	**19.14**	**0.0011**	
t	0.0267	2	0.0134	24.25	0.0013	40.271
Sd	0.0264	2	0.0132	24.05	0.0014	39.819
Vct	0.0099	2	0.0050	8.96	0.0158	14.932
Error	0.0033	0	0.0000			4.977
Total	**0.0663**	**12**	**0.0055**			**100**
Cn46.CV1.G.V1400x40x203x35m/s						
Number of obs:	13		R-squared:		0.9854	
Root MSE:	0.0115		Adj R-squared:		0.9708	
Model	**0.0540**	**12**	**0.0045**	**67.46**	**0.0000**	
t	0.0223	2	0.0111	**87.7**	0.0000	40.608
Sd	0.0234	2	0.0117	**85.7**	0.0000	42.631
Vct	0.0084	2	0.0042	**31.56**	0.0007	15.303
Error	0.0008	0	0.0000			1.457
Total	**0.0549**	**18**	**0.0030**			**100**

Regression and Verification of Surface Roughness Model

From tables4 and 5, the relationship between surface roughness and grinding conditions was investigated. The most suitable regression of surface roughness was a quadratic regression as given in Equation 1 for Cn46.TB$_1$.G.V$_1$.400x40x203x50m/s grinding wheel and Eq. 2 for Cn46.CV$_1$.G.V$_1$.400x40x203x35m/s grinding wheel.

When grinding ШХ15 steel using Cn46.TB$_1$.G.V$_1$.400x40x203x50m/s grinding wheel, coefficient of determination$R^2 = 0.9556$.

$$R_a = 0.3424 - 6.9415 * t + 0.2879 * S_d - 0.0051 * V_{ct} + 85.7692 * t^2$$
$$-1.23\text{x } 10^{-7} * S_d^2 + 0.0001 * V_{ct}^2 - 1.3569 * t * S_d - 0.0085 * t * V_{ct}$$
$$+0.0053 * S_d * V_{ct} \quad (1)$$

When grinding ШХ15 steel using Cn46.CV$_1$.G.V$_1$.400x40x203x35m/s grinding wheel, coefficient of determination $R^2 = 0.9975$.

$$R_a = 0.2563 - 8.2319 * t + 0.9447 * S_d + 0.0270 * V_{ct} + 84.2308 * t^2$$
$$-0.4999 * S_d^2 - 0.0004 * V_{ct}^2 - 1.3274 * t * S_d + 0.0430 * t * V_{ct}$$
$$+0.0027 * S_d * V_{ct} \quad (2)$$

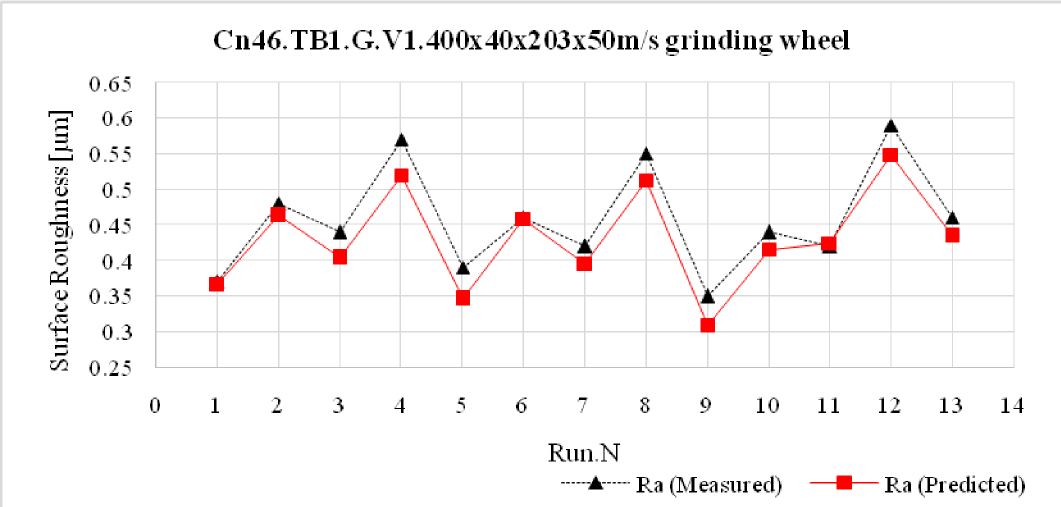

Figure 2: Comparison of Measured and Predicted Surface Roughness when using Cn46.TB1.G.V1.400x40x203x50m/s Grinding Wheel

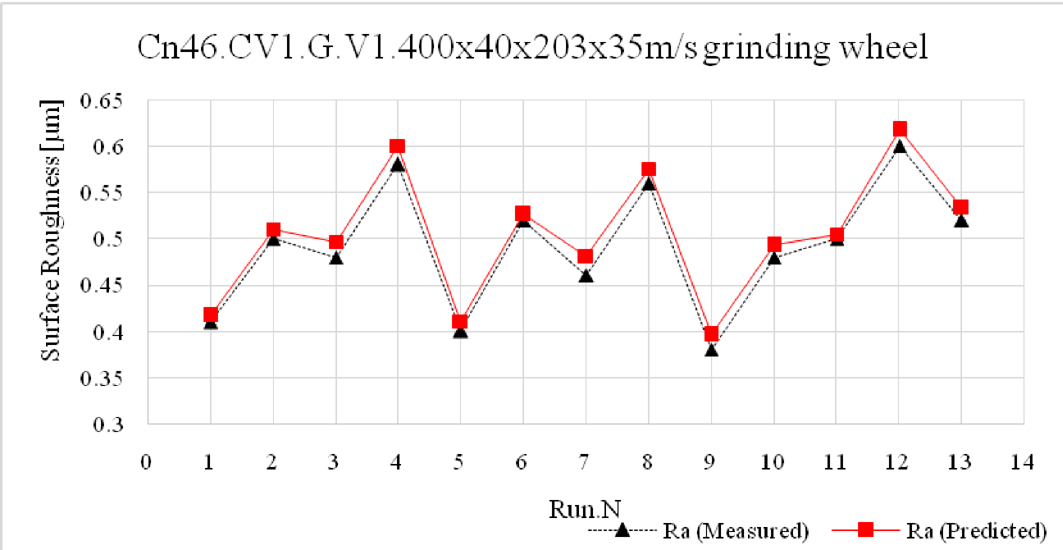

Figure 3: Comparison of Measured and Predicted Surface Roughness when using Cn46.TB1.G.V1.400x40x203x50m/s Grinding Wheel

The verification results of surface roughness model were described in Figure 2 and Figure 3. As seen from these figures, the predicted results were very close to the experimental results. There is a very good relation between predicted values and test values. The R^2 values of the equations obtained by quadratic regression model for surface roughness was found to be bigger than 95.5%. These results showed that the quadratic regression model was shown to be successfully investigated of surface roughness in grinding processes.

Optimization

The optimization process of surface roughness is based on the developed response surface model and the application of the floating-point genetic algorithm for minimization problems. A selected population of solutions initially evolves from a given number of individuals by employing genetic mechanism. This is performed with an adopted optimization program, developed in Excel [6]; population of appointed size is randomly chosen between the lower and upper values and undergoes a process of evolution in a simulated competitive environment. The latter mechanism consists

of tournament selection, linear crossover and non-uniform mutation. Both bit-exchange crossover and bit-flip mutation occur at every cycle, according to assigned probabilities. Optimization has been achieved by determination of three control parameters of the genetic algorithm; the size of the population and the probability values for crossover and mutation, their value are 100, 0.25 and 0.05 respectively, as [7, 8, 9]. The fitness of each individual is evaluated (Figure 4. to Figure 5.).

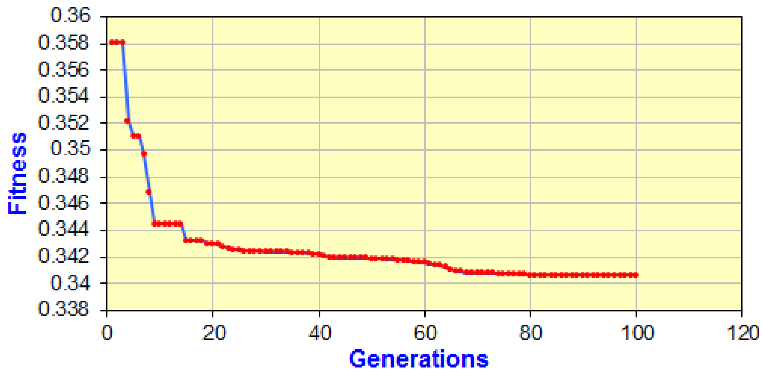

Figure 4: Genetic Algorithm Graph for Grinding ШХ15 by Cn46.TB$_1$.G.V$_1$400x40x203x50m/s

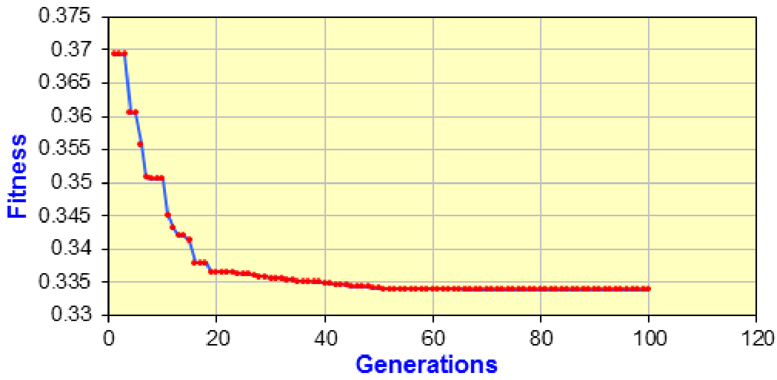

Figure 5: Genetic Algorithm Graph for Grindingшx15 by Cn46.CV$_1$.G.V$_1$400x40x203x35m/s

Table 6: Optimization Value of Cutting Parameters and Surface Roughness of Workpiece

Workpiece/ Grinding Wheel	Optimization Value of Cutting Parameters						$R_a(\mu m)$
	Code Value			Actually Value			
	t	S_d	V_{ct}	$t(mm)$	S_d (m/min)	V_{ct} (m/min)	
ШХ15/Cn46.TB$_1$.G.V$_1$400x40x203x50m/s	-0.9972	-0.9999	-0.9999	≈ 0.005	≈ 0.45	≈ 25.12	0.341
ШХ15/Cn46.CV$_1$.G.V$_1$400x40x203x35m/s	-0.9994	-0.9995	-0.9999	≈ 0.005	≈ 0.45	≈ 25.12	0.334

The Optimized values of cutting parameters in two cases were determined and listed in Table 6.The optimum values of surface roughness are 0.341 μm (using Cn46.TB1.G.V1.400x40x203x50m/s grinding wheel) and 0.334 μm (using Cn46.TB1.G.V1.400x40x203x50m/s grinding wheel). These results were obtained at cutting depth of 0.005 mm, at a feed rate of 0.45 m/min, and a workpiece velocity of 25.12 m/min when using both two types of grinding wheel.

CONCLUSIONS

This paper builts the relationship between surface roughness and cutting parameters when grinding ШХ15 steels using two types of Hai Duong grinding wheel. Depending on the analysis of experimental results, the conclusions of this study can be drawn as follows.

- The most important factors affecting on the surface roughness were depth of cut and feed rate, and the third factor influencing on the surface roughness was workpiece velocity.
- The the most suitable regression of surface roughness was a quadratic regression. The predicted models of surface roughness were successfully verified by experimental results.
- The tendency of the surface roughness is the same that one of cutting force's amplitudes. So, the optimal value was determined for surface roughness that is one of the most important values to improve the quality of machining product.
- The Genetic Algorithm was used to find the optimal value of surface roughness. In this study, the optimum value of surface roughness is about 0.34 μm that was obtained at cutting depth of 0.005 mm, at a feed rate of 0.45 m/min, and a workpiece velocity of 25.12 m/min. These results were found when using both two types of grinding wheel.

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